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To: Office of Drinking Water Technical Staff

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From: Membrane Technology Committee

Subject: Water – Design and Construction – Treatment
Hollow Fiber, Positive Pressure Driven
Microfiltration and Ultrafiltration Membrane Filtration Technology

Delete: Working Memo 723 and 830

Ref: Working Memo 844, 851, and 869

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I. Purpose

The purpose of this working memo is to provide guidance for the use of membrane filtration technology for pathogen and turbidity removal. Under the guidelines of this working memo, conventional process approval procedures for microfiltration and ultrafiltration, hollow fiber, positive pressure driven membrane filtration technology may be followed (§12 VAC 5-590-200). Under the guidelines of this working memo, a provisional waterworks operation permit is not required (§12 VAC 5-590-290). Such guidance is given in the context of the following:

- Membrane filtration for pathogen removal is still in the early developmental stages in the United States. Adequately documented, full-scale experience is not widespread.
- The United States Environmental Protection Agency (EPA) is developing regulations containing design and implementation conditions for the degree of credit awarded for removal of *Cryptosporidium*.
- The United States Environmental Protection Agency (EPA) is finalizing a guidance manual (scheduled to be completed by the Fall of 2004) that will provide additional information and procedures for meeting these criteria. Any guidance given at this point in time will need to be reviewed and adjusted as necessary relative to this future national regulation and

guidance document. Draft EPA regulations and guidance are available at www.epa.gov.

II. Membrane filtration definition

Membrane filtration is defined as a pressure-driven separation process in which particulate matter larger than 1 µm is rejected by a non-fibrous, engineered barrier primarily through a size exclusion mechanism and which has a measurable removal efficiency of a target organism that can be verified through the application of a direct integrity test (DIT). This working memo is intended to include the common membrane technology classifications of microfiltration (MF) and ultrafiltration (UF) using hollow fibers. This working memo does not cover other membrane technologies (such as vacuum-driven hollow fiber membranes), other membrane configurations (such as spiral wound membranes), or membranes applied for purposes other than turbidity and suspended pathogen removal (such as removal of dissolved solids).

For consistency two definitions are provided:

- Module means the smallest component of a membrane unit in which a specific membrane surface area is housed in a device with a filtrate outlet.
- Unit means a group of membrane modules that share common valving which allows the unit to be isolated from the rest of the system for the purpose of integrity testing or other maintenance.

The United States Environmental Protection Agency (USEPA), *Membrane Filtration Guidance Manual* glossary should be consulted for additional definitions.

III. *Giardia* cysts and *Cryptosporidium* oocysts removal credits

Under the guidelines of this working memo, the maximum *Giardia* cysts and *Cryptosporidium* oocysts removal credit is 3-log for each.

IV. Virus reduction credit and reduction required

Virus removal credit by membrane filtration is zero.

Virus reduction post membrane filtration is required so that virus inactivation and other microbial minimum treatment requirements are achieved. A 4-log inactivation of viruses by disinfection treatment is required. Based on current EPA CT tables, a 4-log virus inactivation can be achieved at a CT of 12 at a pH of 9 or less. See the SWTR Guidance manual for virus inactivation tables.

V. Overview of the various membrane filtration processes

The EPA *Membrane Filtration Guidance Manual* contains an overview of the various membrane filtration processes, including descriptions of the various classes, membrane material, geometry, module construction, driving forces, basic principles of design and operation, and hydraulic configuration(s).

Emphasis is given to the manner in which each of these characteristics relates to membrane filtration applied for pathogen removal.

VI. Hydraulic modes of operation

Overview of hydraulic modes of operation:

- Hollow fiber flow path can be either inside-out or outside-in.
- Hydraulic configuration is either deposition mode or the suspension mode.
- In any of the suspension modes or its variations, the ratio of the concentration of particles in suspension on the feed side of the membrane to the concentration of particles in the influent feed (volumetric concentration factor [VCF]) shall be ≤ 4.
- The deposition mode may include a periodic back pulse with air, filtrate, and/or oxidants to dislodge particles trapped on the membrane surface.
- Crossflow is a type of suspension mode operation. Air and/or water are continuously or intermittently applied as a scouring force to keep particles suspended or to re-suspend deposited particles. Where a portion of the reject is recycled to the suction side of the feed pump, the mode is called small volume crossflow. To prevent excessive concentration of particles on the feed side of the membrane, recycle must be limited to 10% of the feed flow. Accumulated solids must be removed from the system during the backwash cycle. The maximum volumetric concentration factor shall be 4 over the course of any filtration cycle.
- Feed-and-bleed is a type of suspension mode operation similar to crossflow in that particles are held in suspension on the feed side of the membrane while a continuous concentrate waste stream removes particles from the system. Backwashing essentially removes all the particles from the system. As a result the VCF is reduced to zero at the completion of each backwash cycle. The maximum VCF shall be 4 at the end of the filtration cycle.

VII. Design and Operation Issues

The EPA *Membrane Filtration Guidance Manual* should be consulted for system design and operation of membrane unit processes including pretreatment, backwashing, chemical cleaning, integrity testing, and post-treatment. Additionally the same section of the *Guidance Manual* discusses some of the most significant design issues associated with flux, water quality, temperature compensation, cross connection control, and reliability. Residuals and concentrate disposal are also discussed.

Construction sequence, customer service, and waste disposal must be addressed. Waste disposal includes wastes generated from removal of the membrane preservation solution, flushing the system prior to membrane installation, initial system disinfection, and performance verification period operation.

Membrane filtration units may be fitted with block and bleed valve arrangements or removable spools to eliminate the potential for backflow. See the same section of the *Guidance Manual* for additional information.

All membrane materials and associated piping, etc. must be certified NSF/ANSI Standard 61.

Chemicals used in any membrane unit cleaning process shall be NSF 60 certified or shall be generally recognized as safe.

Design and operational issues to be evaluated are included in Appendix A, Preliminary Engineering Report section. This list is not all inclusive.

VIII. Product specific challenge test

Removal efficiency of microbial pathogens of concern shall be established through a product specific challenge test. Specific and detailed challenge test criteria must be followed. Challenge testing demonstrates the removal efficiency a membrane module is capable of achieving. Based on the *Membrane Filtration Guidance Manual* challenge testing criteria, a membrane module can potentially demonstrate up to 6.5-log removal of the challenge particulate if removed to the detection limit. Only those specific products where challenge testing results calculate to 5.5-log removal or greater will be considered for acceptance.

The EPA *Membrane Filtration Guidance Manual* provides specific criteria and procedures for meeting the challenge test criteria. The EPA *Membrane Filtration Guidance Manual* or equivalent criteria shall be used for the following challenge test requirements:
- Full-scale vs. small-scale module testing
- Appropriate challenge particulates
- Challenge particulate concentrations
- Test operating conditions
    1. Maximum recovery
    2. Representative VCF
    3. Maximum flux
- Calculation of removal efficiency
- Establishment of a quality control release value (QCRV) for a non-destructive performance test (NDPT)

Challenge testing must be conducted using *Cryptosporidium* oocysts or a surrogate that has been determined to be removed no more efficiently than *Cryptosporidium* oocysts. Indirect water quality measurements such as turbidity, particle counting, or conductivity shall not be used to determine removal efficiency of pathogens. The concentration of the organism or surrogate used during challenge testing must be determined using a method capable of discretely quantifying the specific challenge particulate used in the test.

The challenge test protocol and results must demonstrate the removal efficiency. Previously conducted challenge testing demonstrating acceptable removal and not significantly deviating from the *Membrane Filtration Guidance*

Manual challenge test criteria will be considered. The challenge test protocol and results used to demonstrate removal efficiency acceptance must be submitted as part of the Preliminary Engineering Report.

Modified membrane modules must be retested if the modifications may affect the membrane characteristics, removal efficiency, or the NDPT results and associated QCRV. Some examples of modifications requiring retesting include but are not limited to: membrane material, membrane backing material, pore size distribution, porosity, permeability, or symmetry. Modifications to the hydraulic configuration of a filtration system will require retesting if the concentration of suspended solids on the feed side (VCF) may be higher. An example of an increased VCF is when the configuration was originally tested in the dead end (deposition mode) and the proposed configuration is crossflow (suspension mode).

The product specific challenge test report must include the methodology used in determining the QCRV for the NDPT. The QCRV must be sufficient to justify a 5.5 LRV and a 3μm resolution.

IX. Quality control release value

The NDPT and QCRV are necessary because the challenge test criteria do not require that every membrane module be subjected to challenge testing. A non-destructive performance test, e.g., bubble point test or pressure decay test may be applied to each production membrane module in order to verify removal efficiency of those that did not undergo challenge testing. A quality control release value (QCRV) must be established for the NDPT that is directly related to the minimum removal efficiency capability of the membrane filtration process of 5.5-log removal as demonstrated during challenge testing. Membrane modules that do not meet the established QCRV are not eligible for the removal credit demonstrated during challenge testing.

Each module shall be accompanied by documentation of the successful application of the product specific quality control release value. The documentation shall be provided for each module to the waterworks owner or its representative for acceptance.

X. Direct integrity test

In order to receive *Giardia* cyst and *Cryptosporidium* oocyst removal credit, the removal efficiency of a membrane filtration process must be routinely verified during operation using direct integrity testing. The direct integrity test must be applied to the physical elements of the entire membrane unit, including membranes, seals, potting material, associated valves and piping, and all other components which could result in contamination of the filtrate under compromised conditions.

The currently acceptable direct integrity test is a pressure-based test based on bubble point theory, which involves applying a positive pressure to one side of a wetted membrane barrier and monitoring for pressure loss or pressure decay in order to establish whether an integrity breach is present. The DIT system must be capable of preprogrammed automatic operation or manual initiation.

The direct integrity test applied to a membrane unit must meet performance criteria for resolution, sensitivity, and frequency as follows:

- Resolution: The direct integrity test must be responsive to an integrity breach on the order of 3 µm or less.
- Sensitivity: The direct integrity test must be able to verify a 4.0-log removal value (LRV).
- Frequency: A direct integrity test must be conducted, as a minimum, on each membrane unit at least daily.

The DIT sensitivity is primarily a function of the smallest, reliably measurable response the equipment can detect, referred to as the threshold response. Sensitivity may also be affected by the diffusion of air through the water in the wetted pores of the membrane, referred to as the threshold response.

The EPA *Membrane Filtration Guidance Manual* describes the DIT and how its results are used to determine both sensitivity and the removal efficiency.

Direct integrity test parameters:

- Use of the new ASTM D 6908-03 Standard, Practice A, Pressure Decay Test for DIT procedures is required with the following stipulations:
    1. In section 9.1.5, the time for the decay rate determination shall be at least five minutes
    2. In section 9.1.7, the measured pressure decay rate may be corrected by subtracting the pressure decay due to diffusive air flow from the measured pressure decay
    3. In section 9.1.8, the more conservative approach should be taken assuming all pressure decay is related to integrity
    4. In section 9.3, integrity test initial pressure should be calculated using conservative membrane property parameters in determining the minimum required initial test pressure required to meet the 3µm resolution criteria. Intrinsic properties of manufactured membrane pores are more than likely not the same as the properties of defects or tears or oversized holes in the membrane material. Therefore, the conservative values of pore shape, contact angle, and surface tension must be used. Additionally, any hydrostatic backpressure must be included in calculating the minimum initial test pressure. Using the conservative values of K=1, θ=0, and s=74.9 dynes/cm @ 5 degrees C results in initial P_{test} = 14.5 psi + maximum hydrostatic backpressure.

       If the pressure at the end of the test is below the initial pressure calculated above then the test failed. Initial calculated test pressure should be increased to account for some baseline decay so as to ensure adequate applied pressure throughout the duration of the test.

As a result, the minimum initial test pressure must be:
P_{test} = 14.5 psi + hydrostatic backpressure + baseline decay.

- DIT parameters must be viewable by the operator, as follows:
    1. Initial pressure
    2. Final pressure
    3. Stabilization period (if applicable)
    4. Decay rate determination duration
    5. Decay rate
    6. LRV (optional)

Direct integrity test operational control criteria:

- Optimization – To achieve optimized removal of particulate pathogens, the units should be operated at or below the DIT pressure decay rate (psi/min) corresponding to a LRV of 4.0.
- Alarm – To alert the operator of potential problems, an alarm must be energized and the operator informed when the DIT pressure decay rate (psi/min) corresponding to an LRV of 3.5 is reached.
- Shut down – Any membrane unit reaching the DIT pressure decay rate (psi/min) corresponding to a LRV of 3.0 (independent of any indirect monitoring data) must be taken off line immediately, for diagnostic testing and subsequent repair.
- Operating a single unit or more at a DIT pressure decay rate (psi/min) corresponding to a LRV of < 3.0 may result in a boil notice being issued.

XI. Diagnostic testing

Diagnostic testing equipment shall be provided to isolate a compromised module or fiber or both. A means to visually inspect modules while simultaneously conducting the DIT must be provided. Alternatively, sonic testing equipment providing a relative accelerometer reading shall be provided where visual inspection cannot be performed. Sonic testing equipment is recommended.

Single module bubble testing apparatus to facilitate testing of removed modules shall be provided.

Some diagnostic testing procedures of modules or units after a shutdown alarm condition or other unit isolation diagnostic procedures will require filter-to-waste capabilities.

XII. Continuous indirect integrity monitoring

Continuous indirect integrity monitoring equipment shall be provided as a surrogate measure of membrane unit integrity for operational control and shall be provided to determine compliance with the turbidity treatment technique.

Continuous indirect integrity monitoring is required between direct integrity testing to provide some measure of performance assessment. As a minimum, continuous indirect integrity monitoring shall be by continuous turbidity monitoring of the filtrate from each membrane unit. "Continuous" means monitoring at a frequency of no less than once every 15 minutes. The minimum acceptable equipment shall be laser nephelometers or particle counters in combination with tungsten-filament lamp nephelometers. Particle monitors are not an alternative to the minimum equipment requirement.

The ability to multiplex these instruments may help to minimize the associated cost of utilizing laser nephelometers. In multiplexing, multiple sensors are connected to a single laser light source, detector, and control system via fiber optics. Sensors can be attached to monitor the filtrate from each membrane unit or individual membrane modules, if desired.

Indirect integrity monitoring, filtrate turbidity operational control criteria:

- Optimization – To achieve optimized removal of particulate pathogens, the units must be operated at or below a filtrate turbidity of 0.1 NTU
- Alarm – To alert the operator of potential problems, an alarm must be energized and the operator informed when the filtrate turbidity of any unit exceeds 0.1
- DIT triggered - Whenever two consecutive, 15 minute turbidity readings exceed 0.15 NTU for any one unit, the DIT is automatically initiated on that unit.
- Shut down –Any membrane unit filtrate turbidity reaching 0.3 NTU or greater (independent of any direct monitoring data) must be taken off line immediately for necessary diagnostic testing and subsequent repair.

Turbidity treatment technique compliance is based on a filtered water turbidity of less than or equal to 0.3 NTU in at least 95% of the measurements taken each month. Samples must be representative of the waterworks' filtered water. Additionally, the turbidity level of representative samples of a system's filtered water must at no time exceed 1 NTU. See Working Memo 869 for additional details.

Filtered water (point of entry) turbidity levels exceeding 1.0 NTU in conjunction with other factors warrant the issuance of a boil water notice. See Working Memo 844 for additional details.

XIII. Instrumentation

a. Continuous Reading and Recording

Continuous reading and recording instrumentation systems shall be provided as indicated below:

- Source water turbidity monitoring by tungsten-filament lamp nephelometers
- Feed water turbidity monitoring by tungsten-filament lamp nephelometers (between prefiltration and each membrane unit) is recommended.
- Pressure drop across raw water prefiltration or prefiltration on the membrane unit, as appropriate, read only
- Pressure drop across the membrane modules, i.e. transmembrane pressure,

- o Filtrate turbidity monitoring of each unit by laser nephelometers or particle counters in combination with tungsten-filament lamp nephelometers
- o Date, time, and results of the direct integrity test on each unit

Continuous reading and recording instrumentation system shall be provided at the waterworks entry point to the distribution system for disinfectant residual. Neither combined filtrate nor point of entry continuous reading and recording of turbidity is required. However, operator attendance and grab sample monitoring requirements may necessitate continuous reading and recording of combined filtrate turbidity, preferably prior to entry into the clearwell.

Continuous reading instrumentation means an electronic sensor continuously reads the parameter and the parameter is displayed in real time. Continuous recording means one data point is stored in memory or printed at least every 15 minutes. The one data point that is stored or printed is a snapshot of the parameter at that time; it is not an average of previous data points. Equipment capable of producing a hard copy (or equivalent electronic file) showing daily trends including maximum, minimum, and average values must be provided. Electronic files must be backed up to removable media on a daily basis.

Continuous reading instrumentation requires a continuous flow through the instrument sensor. During periods of shut down, backwashing, chemical cleaning, or other maintenances activities, the flow through the sensor may stop and the instrument sensor may go dry resulting in erroneous readings. These erroneous readings may create an alarm condition and shutdown the unit or prevent its restarting. Provisions should be included to prevent sensors from going dry.

b. Air Entrainment Error

Air entrainment error caused by air bubbles being introduced into the system either during production, backwashing, chemical cleaning, or integrity testing may be falsely detected as particulate matter, artificially increasing the instrument reading. Consequently, after a backwash cycle or chemical cleaning (particularly if air is utilized in the process), instrument measurements may not be representative of filtrate quality until any entrained air is purged from the system. This purge time will vary between different membrane filtration systems and their respective backwash or chemical cleaning practices. Bubble traps may be employed to minimize or eliminate this error.

If removal of entrained air error is unsuccessful, the PLC may be programmed to verify an alarm or shutdown operational control condition immediately following an operation resulting in air entrainment so that the DIT is not triggered. Significant and continuous air entrainment problems will be addressed on a case by case basis.

c. Computers and SCADA

- o Automated systems used to display and record data or control functions and that are connected to computers or networks with an internet link or that use a radio system shall have sophisticated encryption to prevent hacking.

- o A backup power supply shall be provided to allow orderly shutdown of the computer system and prevent corruption of data. The protection shall cover every connection to all outside service providers such as power, cable, telephone, DSL, ISDN, etc.
- o Adequate hardware shall be in place to allow a high degree of SCADA and computer system reliability and data security. Acceptable methods of meeting this requirement include:
    1. Providing side-by-side PCs capable of performing the same tasks, with the ability to rotate the operation and monitoring tasks between the two PCs, and with these PCs having mirrored hard drives or
    2. Installing duplicate mirrored hard drives in a single PC.
- o Adequate hardware and facilities shall be provided for data archiving. Providing the means to back-up data stored on hard disk drives to removable media on a daily basis and to maintain a back-up copy of archived data at a secure off-site location would meet this requirement.
- o SCADA and computer systems shall have adequate protection from voltage surges and spikes on the power supply and external data links.
- o Except for local displays and sensors designed for the environment, all electronic elements shall be located in an area free of excessive moisture, corrosive chemicals or excessive heat or shall be protected by an appropriately rated NEMA enclosure.
- o SCADA and computer systems used to meet the continuous recording requirements of the *Waterworks Regulations* shall record an observation on a minimum frequency of once per quarter hour, unless a greater recording frequency is required.
- o SCADA and computer systems used to meet the indicating and recording requirements of the *Waterworks Regulations* shall provide dedicated and continuous displays that show a minimum 24-hour trend of results for each parameter. The display panel(s) shall be located in an area where it can be routinely viewed by the operators. Sufficient display panels and software should be provided to allow the data to be observed without changing screens. However, if changing screens is necessary, then the displays of the required data must be easily accessible without excessive scrolling through multiple screens.
- o In the event of computer malfunction, all mandatory continuous in-line analyzers shall feature a display of the test results that is independent of any central computerized data system. Providing a separate display at each in-line unit would meet this requirement.
- o Manual Operation: Waterworks pumps, chemical feeders and other essential electrical equipment controlled through a SCADA or an automated control system shall have the capability for independent manual operation through a HOA switch.

d. Laboratory Instrumentation

Laboratory type, bench instrumentation units shall be provided as necessary to perform daily grab samples, comparisons of the continuous instrumentation, and provide for substitution of continuous reading where equipment is out of service. Bench units shall include turbidity, disinfectant residual, temperature, and pH.

e. Flow Rate Measurement

Flow measuring equipment for measuring or calculating the following:

- Source water, gpm and totalized
- Filtrate from each unit, gpm and totalized
- recycle to each unit, % of feed flow, if applicable
- entry point, gpm and totalized
- waste

f. Alarms and Automatic Shutdown

An alarm system shall be provided which will report alarm conditions and will shutdown the treatment plant and entry point flow. All alarm conditions shall be reported to a location manned 24 hours per day or activate an auto-dialer. The following alarm and shut down set point conditions shall be provided and will be determined on a case-by-case basis:

- Source water turbidity
- Feed water turbidity – where appropriate
- Low feed water flow
- Filtrate turbidity from each unit exceeding operational control criteria
- Membrane direct integrity test exceeding operational control criteria
- Excessive transmembrane pressure at each unit
- Entry point disinfectant residual, high and low
- Low air pressure

Where the membrane may be easily damaged or rendered inoperable due to excess feed water turbidity or debris, feed water monitoring equipment and alarm and shutdown set points shall be required for each unit. The alarm and shutdown set points will be determined on a case-by-case basis with the manufacturer's warranty considered.

g. Sample Taps

Sample taps shall be provided to monitor the following:

- source water
- source water storage tank effluent
- feed water after prefiltration
- filtrate from each membrane unit
- combined filtrate from all units
- Additional sample taps to monitor the presence of cleaning solutions used in either the backwash or cleaning operations.

XIV. Reliability

The need for treatment units on line, units in standby, duplication of units, and components or spare parts on hand or readily available will be decided on a case-by-case basis.

The number of membrane units will be a function of the overall waterworks design and storage capacity and the design maximum daily demand. Multiple membrane units should be provided where design capacity exceeds 0.5 MGD. Two units shall be provided where design capacity exceeds 2 MGD.

For groundwater or surface influenced groundwater sources, continuous withdrawal of source water must be considered when sizing treatment facilities. The safe yield of wells as established by conventional 48-hour yield and drawdown testing, is generally not based on continuous pumping and may require reducing the design safe yield to facilitate the continuous operation of a membrane plant.

Redundancy of pumps, motors, chemical feeders, etc. shall be in accordance with the applicable sections of the *Waterworks Regulations*, Manual of Practice.

The membrane treatment plant electrical system and essential electronic components should be closely evaluated for reliability. The environment the electrical system and essential electronic components is subjected to must be addressed by use of appropriate enclosures and environmental control. The need for additional filtering, voltage regulation, surge protection, interference protection, and etc. must be addressed.

Waterworks with greater than one day of domestic storage may not need dual parallel units. Where single units are used in conjunction with excess domestic storage, replacement components and spare parts must be on hand or readily available. As a minimum, a spare programmable logic controller (PLC) shall be readily available.

Appurtenances should be provided and pumping rates should be controllable to facilitate operation with a few modules removed or a membrane unit out of service.

Appurtenances would be necessary to cap-off the module location or isolate the membrane housing from the unit when one or more modules are removed or not in use.

Special consideration shall be given in the design of the building for equipment accessibility, piping locations, noise abatement, and vibration insulation.

XV. Class of Operator and Attendance

a. Class and Attendance

Class and attendance will be in accordance with the *Waterworks Regulations*, Section 12 VAC 5-590-460 Personnel. These attendance requirements take into consideration the unattended automatic start-stop operation of membrane treatment units.

For new waterworks or waterworks employing membrane filtration for the first time, it is strongly recommended that the responsible charge operator be employed prior to construction of the system. Being at the facility during construction will provide maximum familiarity with the new technology.

b. Minimum Class

A minimum of a Class IV operator will be required to give attendance at the waterworks each day of operation for sufficient time to perform necessary monitoring and process evaluation, and to make any process adjustments deemed necessary. The necessity of public health protection, the complexity of pretreatment, changing or poor source water quality, and permitted capacity will necessitate the operator class being upgraded to Class III or higher.

- A Class IV operator must respond to any alarm-generated shutdown prior to restarting.
- A Class IV operator must be on site to manually start the chemical cleaning process.
- Daily attendance means physically at the plant every day when the plant is scheduled to operate.
- A Class IV must be on call when the plant is scheduled to operate.

XVI. Performance Verification

a. Initial Start-Up

Flushing the membrane preservation solution from the modules and the system must be completed prior to initial disinfection. Initial system disinfection of the entire system, including both feed and filtrate piping, must include recirculation of the disinfectant solution through the system. The disinfectant solution used must be compatible with the membrane material. Upon completion of disinfection, the entire system, including the membranes, should be thoroughly flushed. The flushing and disinfection steps are complete when there is no detectable disinfectant residual and subsequent bacteriological sampling indicates the absence of Coliform organisms. ANSI/AWWA Standards C 651, C 652, and C 653 provide guidance for disinfecting waterworks.

b. Thirty-Day Start-Up Period

Upon completion of construction of the membrane treatment facility and the initial start-up procedures, a performance verification period of approximately 30 days shall start. The verification period shall include at least one period of 48 hours of continuous operation. During the performance verification period, the design criteria and performance requirements of the specifications, including the design capacity and flux, shall be confirmed. Additionally, operational control performance criteria, alarm set points, shutdown set points, integrity testing performance criteria, backwash initiation and termination criteria, chemical cleaning initiation and termination criteria, and emergency procedures shall be verified and documented.

Initially, the direct integrity test shall be conducted two to four times per day until the results stabilize. False positive direct or indirect integrity test results can be minimized by first characterizing typical system performance under a variety of operating conditions (such as after a backwash) and subsequently programming the data acquisition system to account for regularly occurring data aberrations of previously quantified magnitude and duration that are known not to represent an integrity problem, even if operational control performance criteria or integrity testing performance criteria are exceeded.

Operator training as required by the contract documents shall be performed during this startup period if not previously conducted.

c. Engineer's Substantial Completion Statement
Performance must be verified by a licensed engineer prior to issuance of the waterworks operation permit. The performance verification period report shall be part of the engineer's substantial completion statement. The data contained in the report will be used in developing the waterworks operation permit, special conditions in section XVIII.

XVII. Operation and Maintenance Manual

The specifications shall include a requirement that a detailed, site specific, Operation and Maintenance Manual shall be provided by the engineer directly to the waterworks owner (ODW will provide technical assistance). The operator in responsible charge should have sufficient time to review the O & M Manual prior to the manufacturer's onsite training and thirty-day start up period.

The manufacturer supplied Operation and Maintenance Manual shall contain readily understood information on the recommended or required maintenance requirements for each piece of equipment. The manual shall also contain readily understood procedures for the proper operation of the membrane units and associated appurtenances including software user instructions. Additionally, the manual shall contain a trouble shooting guide. The manual shall identify specific equipment or software issues which the owner or the operator in responsible charge has no access to for operation and maintenance purposes. The manual shall be specific as to potential damage or any warranty issues involved. Additionally, the owner shall be advised which O&M issues must be addressed through a service call.

The *Environmental Technology Verification Protocol* prepared by the NSF and the EPA, contains detailed recommendations for O&M Manual criteria. The publication is available at http://www.epa.gov/etv/. Additionally, the EPA *Membrane Filtration Guidance Manual* should be consulted for operational issues to include in the O&M Manual.

XVIII. Waterworks Operation Permit Special Conditions

These operational control criteria and additional operational requirements are imposed on the issuance of the permit to operate as enforceable operational conditions.

a. Operational Control Criteria

The following shall be included in the Waterworks Operation Permit, Engineering Description Sheet as special conditions:

Operational Control Parameter	Alarm Set Point	Shutdown Set Point
Source water turbidity		
Feed water turbidity (optional)		
Direct integrity test	psi/min equivalent to LRV of 3.5	psi/min equivalent to LRV of 3.0
Transmembrane pressure		
Filtrate turbidity	0.1 NTU	0.3 NTU
Disinfectant Residual, Low		
Disinfectant Residual, High		

b. Additional Operational Requirements

The following shall also be included in the Waterworks Operation Permit, Engineering Description Sheet:

- The permitted flux
- The maximum flux set by the manufacturer
- The quality control release value (QCRV) established for the Non Destructive Performance Test (NDPT) that is related to 5.5-log removal efficiency.
- The direct integrity test must be conducted upon completion of any chemical cleaning process, diagnostic testing, scheduled maintenance, or repairs.
- The direct integrity test must be conducted, as a minimum, on each membrane unit at least daily.

XIX. Reporting and Recordkeeping

a. Monthly Operations Report

An example Monthly operations Report form is in Appendix C. The appendix includes instructions for each item in the MOR. The MOR form and instructions are self-explanatory. The MOR form is an Excel spreadsheet and the instructions are in Word.

Summary reports shall be submitted with the Monthly Operations Report as note below as conditions dictate:

- Summarize all alarm and shutdown conditions
- Advise of all diagnostic testing and subsequent repair steps taken and follow up DIT results
- Summarize any DITs which were triggered by indirect integrity testing

Additionally, those applicable report forms associated with the various surface water treatment rules shall be submitted with the MOR.

b. Sanitary Survey Report

Working Memo 851 contains appropriate sanitary survey report forms.

c. Membrane Module Records

Detailed records for each membrane module should be kept according to each module serial number. Records should include dates, location, factory test data, repairs, replacements, etc. for each module.

XX. Existing Membrane Filtration System

Existing membrane treatment systems that have complied with Action Memo 1433 will not be required to comply with all aspects of this working memo. No changes to existing membrane treatment systems will be required until LT2 is effective.

Any significant modification to the previously approved system, the membrane barrier, or module configuration would require compliance with this working memo. Significant modifications may include but not be limited to: change in membrane material chemistry, change to seals, or change to potting material design.

For those MF & UF hollow fiber, positive pressure driven membranes approved prior to the effective date of this Working Memo, acceptance was based on an absolute cutoff of 1µm or less as demonstrated in various challenge tests and providing a 0.5-log inactivation in the disinfection treatment process. Failure was defined as loss of integrity. Loss of integrity was defined by the pressure based direct integrity test (previously referred to as the pressure decay test) initial pressure, and duration. Below are the minimum DIT criteria for resolution and sensitivity:

- DIT alarm condition must be no greater than 0.3psi/minute
- DIT shutdown condition must be no greater than 0.5psi/minute
- DIT initial pressure must, as a minimum, be in the 15 to 20 psi range.
- DIT duration must be at least 5 minutes, not to include any delay for "stabilization".
- A DIT stabilization period is included in the DIT sequence of most polypropylene membranes due to the material being very hydrophobic and thus absorbing some air. Where the stabilization period is included in the sequence, the DIT initial pressure after the stabilization delay must, as a minimum, be in the 15 to 20 psi range and the duration from initial pressure reading to the end of the decay test must be at least 5 minutes.

These criteria remain in effect unless the waterworks owner decides to submit data consistent with this guidance for product specific challenge test results and a quality control release value. Site specific criteria for the LRV, DIT performance criteria, indirect integrity monitoring performance criteria, etc. will be necessary.

The cross flow mode of operation was restricted to existing membrane treatment systems which demonstrated crossflow in the PER stage and were operating the crossflow at a maximum 10% recycle. This maximum recycle percentage shall continue to apply.

Replacement modules must be accompanied by documentation showing they meet a Quality Control Release Value consistent with the 3µm DIT resolution requirement and a LRV of 5.5.

Based on previous acceptance criteria (1µm absolute cutoff and 0.5-log inactivation), previously approved microfiltration and ultrafiltration, hollow fiber, positive pressure driven membrane filtration treatment works can be credited with 3-log removal of *Giardia* cysts or *Cryptosporidium* oocysts.

No credit is given for virus removal.

The direct integrity test must be conducted, as a minimum, on each membrane unit at least daily.

Turbidity treatment technique compliance is based on a filtered water turbidity of less than or equal to 0.3 NTU in at least 95% of the measurements taken each month. Samples must be representative of the waterworks' filtered water. Additionally, the turbidity level of representative samples of a system's filtered water must at no time exceed 1 NTU. See Working Memo 869 for additional details.

Appendix A

Preliminary Engineering Report

A Preliminary Engineering Report (PER) is required by 12 VAC 5-590-200 of the *Waterworks Regulations.* The primary purpose of the PER is to demonstrate the adequacy of the proposal to safeguard public health and to comply with the *Waterworks Regulations*. The adequacy and applicability of the design must be demonstrated in the PER by presenting and evaluating operating data from a pilot study, full-scale plant study, or an ETV Report employing the proposed membrane product. See Appendix B for demonstration study and data collection requirements. The secondary purpose of the PER is to evaluate the technical, financial, and managerial capabilities of the potential owner to properly operate and maintain the proposed plant. In summary, the PER shall include the items in Appendices A and B, with emphasis on complying with disinfection and filtration requirements and showing that the owner will be able to provide proper O & M of the plant.

The first step in preparing a PER is to conduct a Preliminary Engineering Conference (PEC). The PEC will establish the method of demonstrating the adequacy of the design, the data necessary to justify the design, and the key elements of the PER. The PEC will determine which type of study will be required for the project. The project engineer may submit information to support eliminating the study requirement. The PEC should establish what data is to be obtained from the study(ies). Following the PEC, the engineer must submit study protocols and the PER key elements (in the form of a PEC summary) to ODW for approval prior to conducting the studies. Normally, these studies will be completed prior to the PER submittal since the studies will provide critical information for the project design outlined in the PER.

In the interest of increasing competition and reducing engineering design time and our review time, the project documents should take the *or equal* approach. Therefore, the PER should evaluate and determine whether the project will take the *or equal* approach. If it will, then the PER would designate those manufacturers that would be considered as *or equal* ; those manufacturers would be considered as pre-qualified bidders. The specifications would then contain requirements for all qualified bidders. If a bidder were not pre-qualified, an addendum to the PER would have to be submitted and approved prior to accepting their bid. If the successful bidder was not providing the equipment that was used as the design basis, then the engineer would have to submit an addendum for the necessary plan revisions.

**Suggested Key Elements
Of the
Preliminary Engineering Conference
And the
Preliminary Engineering Report**

1. Purpose of the proposal
    a. Confirm appropriateness of the process relative to:
        i. Regulatory compliance
        ii. Source water treatability
        iii. Feed water characteristics and limitations
        iv. Level of confidence in the process
    b. Compare effectiveness of alternatives
    c. Establish design criteria
    d. Establish performance levels
    e. Establish operational goals, sensitivities, and constraints
2. Alternatives to compare
    a. Operator in responsible charge and additional operating personnel class and attendance requirements
    b. Operator in responsible charge duties during construction
    c. Membrane specific challenge test protocol, results, and NDPT QCRV
    d. Third party, membrane specific reviews, evaluations, approvals, certifications, listings, etc.
    e. Waterworks design capacity
    f. Effective daily production compatibility with distribution system effective storage
    g. Prefiltration pore size and type
    h. Pretreatment chemical conditioning
        i. Performance comparison
        ii. Operational cost comparison
        iii. Compatibility with membrane
    i. Membrane materials compatible with source water and prefiltration and pretreatment
    j. Hydraulic configuration
        i. Deposition or suspension
        ii. Recycling
        iii. Volumetric concentration factor
    k. Post treatment
    l. Supporting equipment
    m. Instrumentation
        i. Continuous indirect integrity monitoring
        ii. Continuous point of entry monitoring
        iii. Laboratory grade
    n. Proprietary items associated with units
    o. Waste disposal
    p. Operator safety and environmental issues

3. Site specific or product specific treatment objectives or questions
4. Source water quality and quantity
    a. Exceeds a turbidity level of 10 NTU monthly average over a one year period
    b. Organic content – dissolved, particulate, or hydrophobic
    c. Continuous safe yield
5. Productivity Design Criteria
    a. Flux – filtrate flow per membrane surface area
    b. Maximum flux to prevent damage
    c. Critical flux – further increase causes significant decrease in production
    d. Flux at reference temperature of 20 degrees C
    e. Flux at coldest anticipated temperature
    f. Temperature normalized flux
    g. Percent recovery – total required feed flow and total filtrate flow including process water and loss of production
    h. TMP range
    i. Maximum TMP to prevent damage and maximize membrane life
    j. Minimum anticipated TMP over filtration cycle
    k. Membrane resistance – total or intrinsic
    l. Specific flux – temperature and pressure normalized
6. Membrane Units Design criteria
    a. Membrane area at design flow
        i. Total membrane resistance and maximum TMP at coldest anticipated temperature – or -
        ii. Intrinsic membrane resistance and minimum anticipated TMP at coldest temperature
    b. Number of modules per unit
7. Operational performance criteria
    a. Energy requirements
    b. Optimize for maximum membrane life
        i. Flux
        ii. Baseline TMP
        iii. Backwash interval
        iv. Chemical clean interval
        v. Chemical usage
        vi. Waste disposal
8. Operational control parameters
    a. Direct integrity test sensitivity
    b. Indirect integrity test method
    c. Alarm set points
    d. Shut down set points
9. Backwash Trigger
    a. Time, flow volume, increase in TMP, or decrease in flux
    b. Minimize down time and waste volume
    c. Use of pressurized air, oxidants, bases, acids, surfactants, etc.
    d. Backwash solution removal and verification

10. Chemical cleaning
    a. Ability to restore unit to clean, baseline TMP
    b. Heating chemical solution required
    c. Softened and/or demineralized water required
    d. Criteria for determining type and amount and sequence
    e. Cleaning solution removal and verification
11. Influence of operational parameters on performance and production
12. Post-treatment
    a. Chemical conditioning
    b. disinfection
13. Waste disposal
    a. Chemical and solids residuals disposal contact DEQ
    b. Costs for various pretreatment and operational options
    c. Chemical cleaning alternatives and backwash chemicals effects on waste disposal options
14. Sequence of construction
15. Schedule of performance verification period and full scale operation
16. Maintaining existing customer services
17. Project costs
    a. Capitol
    b. Operating
    c. Monthly user fees
18. For existing waterworks – impact on the waterworks technical, financial, and managerial capabilities
19. Project inspection and management

Appendix B

Demonstration Studies

The cost of a pilot study and the potential cost savings from the data obtained should be part of the equipment selection criteria. If a report on a specific membrane treatment product has been issued from the National Sanitation Foundation/Environmental Protection Agency, Environmental Technology Verification (ETV) Program or equivalent, then a pilot or full-scale study may not be necessary.

In order to be considered a conventional process, the membrane alternatives must meet the requirements of this working memo. In doing so, a provisional operations permit will not be necessary. The first, primary consideration should be that the membrane module being considered must have been challenge tested in accordance with Section VIII.

a. Pilot Plant Study
A representative pilot plant study establishes design criteria, identifies operational sensitivities, evaluates effectiveness of alternatives, demonstrates treatability, and may include a challenge test, all based on short-term operational data taken during treatment of the proposed source water or treatment of water very similar to the proposed source water. The pilot study period is generally at least 30 days. Where historical source water data is not available, a longer testing period will generally be necessary to account for seasonal changes in source water characteristics. Alternatively, seasonal source water changes may be artificially induced to simulate worst case conditions. Finally, pilot plant studies require scale-up considerations in the final design. The EPA *Membrane Filtration Guidance Manual* should be consulted for further description of pilot testing considerations.

b. Full-Scale Study + Treatability Study
A second option for the demonstration study is a desktop study of a full-scale plant along with a treatability study of the actual proposed water source. The full-scale study establishes design criteria based on detailed review of design data and long-term operational data from an existing full-sized plant treating water very similar in characteristics to the source water proposed. Operational data available for review should satisfy the monitoring points and frequencies required for Demonstration Studies. Long-term operation should include seasonal variations, which would be expected to occur within 12 months. Use of a full-scale study as the basis for design would generally require a more conservative plant design than if a pilot study were used.

i. Treatability Study
A treatability study on the specific source will generally be required to establish the applicability of the proposed design to the specific source water, to establish operating conditions, and to establish a level of confidence in the operation and maintenance costs and resulting user

fees. The treatability study duration is determined by the manufacturer and the engineer and is generally less time than a pilot study.

Site-specific treatability studies are required to verify:
- o appropriate filtrate flux
- o influent, effluent and filtrate pressures
- o transmembrane pressures
- o product water recovery
- o rate of filtrate flux decline
- o backwash frequency, duration and efficiency
- o cleaning chemical type, sequence, frequency, duration and efficiency
- o pre-filtration and membrane replacement frequencies.

The membrane system must be challenged to worst-case source water conditions to determine the limits of its performance. At least a seven-day continuous operation phase with 48 continuous hours of operation at or above the worst case source water characteristics of record may be necessary to make these determinations. Chemical cleaning shall be conducted at the end of the seven-day period to determine cleaning efficiency and resulting filtrate flux decline. Additionally, sacrificing a membrane to evaluate irreversible fouling may be necessary.

ii. Exception to Treatability Study Requirement
The treatability study requirement may be waived if the water used in the full-scale study is very similar to the proposed source water. Thus, there is the option to proceed to final design upon approval of the PER without further field studies. However, not performing a treatability study may increase the risk of ending up with an unreliable membrane design production capacity. Consequently, though this is a significant cost-saving option, there are some factors to consider before eliminating the treatability study. First, this option should only be considered where the source water quality is good and the design approach is conservative. Secondly, long-term historical source water data is necessary if a treatability study will not be conducted. Levels of water constituents such as microscopic particulates, minerals, dissolved constituents, etc. can greatly affect operation and maintenance costs. The fouling potential, pretreatment operating and maintenance, membrane replacement frequencies, and productivity design issues must be considered when considering whether to conduct treatability study and its duration. All these variables can impact the ability to reliably meet the design water demand by causing excessive backwashes, chemical cleaning, and/or membrane replacement. Therefore, these design risks must be considered and minimized even at the expense of increased cost of a treatability study.

c. NSF/EPA, ETV Report + Treatability Study
A third option for the demonstration study is a desktop evaluation of a NSF/EPA ETV Report and/or Verification Statement along with a treatability study of the actual proposed water source. The purpose of this desktop

evaluation is to conclude whether the proposed membrane product is suitable for the project.

The goal of the EPA's ETV program is to provide credible performance data for commercial-ready environmental technologies to speed their implementation for the benefit of vendors, purchasers, regulators, and the public. The ETV Drinking Water System Center, run by NSF, conducts testing that determines and verifies performance of commercially ready drinking water treatment technologies for use in small communities. ETV does not rank technologies, compare technology performance, label or list technologies as acceptable or unacceptable, seek to determine "best available technology," or approve or disapprove technologies. NSF testing against the *Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants* does not constitute an NSF Certification of the product tested. The membrane filtration verification testing plan contains both mandatory and optional testing protocols. Additionally, the protocol conforming to the challenge testing criteria was only recently developed and available for use in the verification program.

For an explanation of the treatability study requirements, see item b.i. above. A treatability study must always be conducted in conjunction with an ETV Report.

Key Elements

Of

Demonstration Studies

1. Method of demonstrating the adequacy of the design
2. Length of study
3. Responsibilities for operation and maintenance of all equipment
4. Monitoring points and frequency
5. Sampling schedule
6. Lab analysis procedures
7. Field analysis procedures
8. Challenge studies procedures
9. Description of unit under test
10. Support equipment
11. Discharge permit

Monitoring Points and Frequency

For

Demonstration Studies

Parameter	**Sampling Points**	**Sampling Frequency**	**Sampling Technique**
Turbidity	Source or Feed & Filtrate	Continuous	In-Line Monitor
Particles ≥2 um	Source or Feed & Filtrate	Continuous	In-Line Monitor
Temperature	Feed	Daily	Grab
TOC	Source or Feed & Filtrate	5 Samples	Grab
SDS-TTHM & HAA5	Source or Feed & Filtrate	5 Samples	Grab
Hardness	Feed & Filtrate	Weekly	Grab
Alkalinity	Feed & Filtrate	Weekly	Grab
PH	Feed & Filtrate	Weekly	Grab
Iron & Manganese	Feed & Filtrate	Weekly	Grab
TDS & TSS	Source or Feed & Filtrate	Weekly	Grab
Free residual chlorine	Feed & Filtrate	2 hours	Grab
HPC	Source & Filtrate	Weekly	Grab
Total Coliform MPN	Source & Filtrate	Weekly	Grab
Phytoplankton	Source or Feed & Filtrate	2 Samples	Grab

OPERATIONAL			
Elapsed time meter Direct Integrity Test Transmembrane Pressure	Membrane unit Membrane Unit Membrane	At each startup For each process Daily Daily	Operating time and Down time See discussion below psi
Feed Flow	Rate & Total	Daily	gpm & gpd
Feed Pressure	Influent	2/day	psi
Filtrate Flow	Rate & Total	Daily	gpm & gpd
Filtrate Pressure	Effluent	2/day	psi
Recycle Flow	Rate & Total	Daily	gpm & gpd
Recycle Pressure	Pump Discharge	2/day	psi
Cross Flow Velocity	Membrane	2/day	fps
Process Flow	Total	Daily	Backwash Chemical clean
Waste Flow	Total	Daily	Calculation

The engineer should tailor the data needs to the specific membrane geometry and source water characteristics.

Monitoring Points and Frequency

Monitoring the source may not give an accurate representation of the concentration of a constituent being applied to the membrane. However, monitoring the concentration of the constituent at the feed point to the membrane may not give an accurate idea of prefiltration capabilities. A decision must be made as to the most appropriate monitoring location or locations for each constituent. Some constituents may require monitoring at three locations to determine the efficiency of each component and associated operational costs.

Turbidity

Purpose is to insure that adequate turbidity removals are occurring. Any turbidity that exceeds 0.1 NTUs in the filtrate water needs to be explained. Also, any fluctuations in the filtrate water turbidity need to be explained. Of particular concern would be significant turbidity fluctuations of the filtrate water, which corresponds to fluctuations of the feed water turbidities. Systems that use an air-assisted backwash may experience turbidity and particle count spikes when the membrane unit goes back into filtration.

pH

The pH must be controlled to protect the membrane material. Also, the entry point pH should be in the proper range to prevent corrosion in the downstream treatment units and distribution system and the Ph should be optimized for the disinfection process.

Total Coliform MPN

There are no criteria for coliform removal by membrane processes. However, some coliform bacteria are removed in membrane processes and the UF membranes would be expected to remove more than the MF. This data will be used to allow comparison of feed bacteria levels to filtrate levels. The feed and Filtrate samples should be taken at the same time to allow a valid comparison to be made. The statistical significance of the comparison will, of course, be greater the longer the study continues.

Particles

The purpose of the data gathered during the testing is to allow operating trends to be determined. The data gathered must be sufficient to determine appropriate operational control parameters. The sensitivity of the particle counters must be such that particles 3 microns and larger can be measured.

Temperature

The temperature data is appropriate to determine the flux of a membrane system vs. the viscosity of the water. Accurate temperature must be kept during the study to gauge the effect temperature will have on plant capacity.

Hardness

Hardness can affect the operation of membranes in two ways. Hardness is related to the stability of the water and corrosiveness of the water. Removal of an excessive amount of hardness may cause scaling problems that may lead to irreversible membrane fouling. The testing frequencies given assume that hardness removal by the membrane is negligible.

Alkalinity

Alkalinity is related to the stability of the water. The frequencies given here would be sufficient if alkalinity removal from the water is negligible. If the membrane used is susceptible to damage due to improper pH of the water, a higher frequency may be appropriate or a more sophisticated pH control would be appropriate.

Heterotrophic Plate Count

HPC (Standard methods 9215) – This test would be appropriate for membranes that may be adversely impacted by bacterial action. The test would show if the disinfection or oxidation processes used on the source water were eliminating heterotrophs that may damage the membrane material. The frequency of the testing should be adjusted according to how susceptible the membrane is to heterotrophic bacteria and the reliability of the source water pretreatment process if provided. Consideration should be given to using the more sensitive method employing R2A agar (S.M. 9215A.6.c.) in determining HPC.

Free Residual Chlorine

Free residual chlorine (FRC) – If prechlorination is not anticipated, the FRC would not need to be measured.

TOC

The TOC content should be broken down into the dissolved and particulate fractions. The dissolved fraction tends to adsorb onto the membrane material while the particulate fraction tends to clog the membrane pores. The dissolved carbon fraction should be characterized as either hydrophobic or hydrophilic. Hydrophobic organic material tends to foul membranes more readily and possibly more permanently. The use of SUVA/UV254 analysis may be useful.

Operational

Elapsed time meter

Operating times and down times are used to determine effective daily production and percent recovery.

Direct Integrity Test

Initially, direct integrity testing should be conducted several times daily until the test results have stabilized. Initial and final DIT pressure results and the test duration data are needed to determine the decay rate. The decay rate and the units log removal value should be determined.

Transmembrane Pressure

A maximum allowable transmembrane pressure and the expected TMP recovery must be determined to establish the TMP operating range. Also, the minimum expected TMP over the filtration cycle should be determined.

Filtrate Flow

The filtrate flow rate and total flow are necessary to determine the design flux, maximum flux, critical flux, flux at reference and coldest temperature, and specific flux. Each of these will be used for design capacity and ultimately for the waterworks permitted capacity.

Waste Flow
Establishing the volume of waste to be disposed of on a regular basis is important to insure that a properly designed waste holding/treatment/conveyance facility is considered.

Process Water and Elapsed Time
The amount of filtrate used for backwashing, chemical cleaning, etc. is needed to determine percent recovery. Percent recovery is determined using the total required feed flow and total filtrate flow including process water and loss of production or down time for processes to occur.

Phytoplankton
Feed and filtrate analysis of phytoplankton will assist in determining the type of contaminants fouling the membranes. Phytoplankton includes diatoms, algae, and pollen.

Alarm Condition
Any alarm condition must be detailed as well as the diagnostic testing and resulting repairs. Upon returning to service, a DIT must be conducted. Any DIT triggered by an indirect integrity test must be reported and detailed.

Appendix C

Monthly Operations Report

for the

Membrane Filtration

Water Treatment Plant

For

Month: ________________________ **Year:** ____________

Chemical	Kind of Chemical	
	NSF 60 compliant?	Used for?
Sodium Hydroxide	yes / no	
Chlorine	yes / no	
Fluoride	yes / no	
Other (name)	yes / no	
	yes / no	
	yes / no	
	yes / no	

Date Waste Basin Last Cleaned of Solids: ______________________

Sonic Testing		
Unit	Date	No. of Modules Tested

Backflush Frequency: ______________________

Number of Connections: ________________ **Population Served:** ______________________________

Signed: ____ **Date Signed:** ____________________________

Print Name: ____________________________________

Title/Operator Classification: __________________________________

Membrane Filtration Water Treatment Plant

Page 2	Operations		Water Volumes					Source Water Quality							Filter Water Quality			
Date	Hours Operator at Plant	Hours Unit in Operation (Hours)	Source/Raw Water Flow (1000 Gals)	Filtrate Volume (1000 gallons)	Recycle (Volume or Percentage of Feed Flow)	Waste Volume (1000 gallons)	Maximum Stabilized Filtration Rate (gpm)	Turbidity - Bench Unit	Turbidity - Inline Unit Instantaneous	Maximum Turbidity - Inline Unit	Raw Water Alkalinity (mg/l)	Raw Water Hardness (mg/l)	Temperature (Celcius)	pH	Turbidity - Bench Unit mNTU	Turbidity - Inline Unit Instantaneous mNTU	Representative Maximum Turbidity - Inline Unit mNTU	Temperature (Celcius)
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2																		
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25																		
26																		
27																		
28																		
29																		
30																		
31																		
Total																		
Average																		

Membrane Filtration Water Treatment Plant

Page 3	Finished Water Quality						Clearwell/Contact Tank		Pre-filter			Integrity Test					
												Test No. 1			Test No. 2		
Date	Free Chlorine Residual Inline Unit - Minimum (mg/l)	Free Chlorine Residual Inline Unit - Maximum (mg/l)	Free Chlorine Residual Grab Instantaneous (mg/l)	Free Chlorine Residual Inline Unit - Instantaneous (mg/l)	Temperature (Celcius)	pH	Chlorine Fed (gpd or lb./day)	Chlorine Dosage (mg/l)	Pressure Loss Across Prefilters (psi)	Trans - Membrane Pressure (ps)	Membrane Modules In - Use	Pressure decay rate (psi/minute)	Starting Pressure (psi)	Ending Pressure (psi)	Pressure decay rate (psi/minute)	Starting Pressure (psi)	Ending Pressure (psi)
1																	
2																	
3																	
4																	
5																	
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28																	
29																	
30																	
31																	
Total																	
Average																	

Water Treatment Plant - CIP Process

DATE	Unit Cleaned	Trans-membrane Pressue Before CIP (psi)	Trans-membrane Pressure After CIP (psi)	Cleaning Solutions Used	Cleaning Solution Water Temperature	pH of Rinse Water After CIP	

SUMMARY REPORT OF MODULE REPAIRS/REPLACEMENTS DITS WHICH WERE TRIGGERED BY INDIRECT INTEGRITY MONITORING UNIT ALARM/SHUTDOWN AND DIAGNOSTIC TESTING/REPAIR/FOLLOW UP

Appendix C

Instructions for using the Monthly Operation Report Form for Membrane Filtration Water Treatment Plants

The monthly operation report form was developed to provide basic information to the operator and the Office of Drinking Water. It was developed assuming only one membrane unit is provided and includes some monitoring which may not be required at all membrane water treatment plants. These instructions only address items which may not be obvious to the operators and engineering staff.

Page 1 Instructions

- Chemical Table - Provide a list of water treatment chemicals in order to verify they are NSF approved.
- Sonic Testing Table - List the unit number, date tested and number of modules sonically tested. Only required at those plants equipped with sonic testing equipment
- Backflush Frequency - Frequency membrane unit performs a flush (i.e. every 60 minutes, etc.). This is typically set by the computer program.

Page 2 Instructions

Operations:

- Hours Operator at Plant – This is only the number of hours an operator is at the treatment plant performing required monitoring and/or performing maintenance at the treatment plant. Do not show the total hours the waterworks is manned.
- Hours Unit in Operation – This is the number of hours the membrane unit is in operation. This includes the time the plant is in the filtration mode and flushing mode. Do not include the time the plant is in the standby mode. Smaller units may have to calculate this value.

Water Volumes:

- Source/Raw Water Flow – This is the volume of untreated water being sent to the membrane unit. Additional columns may have to be added if the flow from the source is different from the flow sent to the membrane unit.
- Filtrate Volume – This is the volume of membrane filtered water being delivered to the disinfection process.
- Recycle (Volume or Percentage of Feed Flow) – This is the volume or the percentage of the feed flow which continuously cycles on the untreated side of the membrane. This column may be omitted if the membrane unit operates in the dead end mode and/or operates in a continuously waste mode.
- Waste Volume – This is the volume of water sent to the waste holding facilities for discharge and includes the volume of backflush water plus water which is continuously wasted when operating in the waste mode. The volume is

typically determined from a waste meter and/or calculated by subtracting the Filtrate Volume from the Source/Raw Water Flow.

- Maximum Stabilized Filtration Rate – This is the maximum stabilized filtration rate (gpm) which the membrane unit operated during the day. This is typically determined using the membrane unit flow rate daily chart and is not the instantaneous flow rate which occurs at unit startup or after a flushing.

Source Water Quality:

- Turbidity – Bench Unit – The daily turbidity as determined using the bench turbidimeter. Required at least 1/day.
- Turbidity – Inline Unit – Instantaneous – The turbidity indicated on the inline turbidimeter when performing a bench turbidity analysis.
- Maximum Turbidity – Inline Unit – The maximum turbidity recorded by the inline turbidimeter.
- Filtered Water Quality:
- Turbidity – Bench Unit – The daily turbidity (in milli NTU's) as determined using the bench turbidimeter. Required at least 1/day.
- Turbidity – Inline Unit – Instantaneous – The turbidity indicated on the inline turbidimeter (in milli NTU's) when performing a bench turbidity analysis.
- Representative Maximum Turbidity – Inline Unit – The maximum turbidity (in milli NTU's) recorded by the inline turbidimeter during the operating daily excluding spikes resulting from physical and/or electrical interferences.

Page 3 Instructions

Finished Water Quality:

- Free Chlorine Residual – Inline Unit – Minimum – The daily minimum free chlorine residual recorded by the inline chlorine residual analyzer.
- Free Chlorine Residual – Inline Unit – Maximum – The daily maximum free chlorine residual recorded by the inline chlorine residual analyzer.
- Free Chlorine Residual – Grab Instantaneous – The free chlorine residual determined by the operator using the laboratory/bench free chlorine residual test equipment. Required at least 1/day.
- Free Chlorine Residual – Inline Unit – Instantaneous – The free chlorine residual indicated by the inline chlorine residual analyzer at the time the operator performs the free chlorine residual analysis using the laboratory/bench free chlorine residual test equipment.

Clearwell/Contact Tank:

- Chlorine Fed – The gallons or pounds of chlorine added to the filtered water.
- Chlorine Dosage – The calculated daily chlorine dosage based on the quantity of chlorine fed and the quantity of water treated with chlorine.

Pre-filter:

- Pressure Loss Across Pre-filter – This is the pressure loss as determined by pressure gauges on either side of the pre-filter units. The value reported is the difference between the upstream pressure gauge and the downstream pressure gauge. This pressure loss alerts the operator of when the pre-filter needs cleaning. This may be omitted if automated cleaning system is provided.

- Pressure Loss Across Pre-filter After Cleaning – This is the pressure loss after the pre-filters have been cleaned as determined by pressure gauges on either side of the pre-filter units. The value reported is the difference between the upstream pressure gauge and the downstream pressure gauge. This may be omitted if automated cleaning system is provided.

Membrane Units:

- Trans-Membrane Pressure – This is the instantaneous pressure across the membrane unit and is typically indicated on the membrane unit computer control system.
- Membrane Modules in Use – The number of membrane modules in operation.

Integrity Test:

- Pressure decay rate – Provided by the membrane unit computer control system and is based on the starting pressure minus the ending pressure divided by the duration of the integrity test. Please note that most existing membrane plants do not currently have the capability to record and report the results of multiply integrity tests. Therefore, some existing plants will only be able to report the last integrity test.
- Starting Pressure – This is the starting pressure of the integrity test as reported by the membrane unit computer control system.
- Ending Pressure - This is the ending pressure of the integrity test as reported by the membrane unit computer control system.

Page 4 Instructions

CIP Process:

- Trans-membrane Pressure Before CIP - This is the instantaneous pressure across the membrane unit indicated on the membrane unit computer control system just prior to a CIP of the membrane unit.
- Trans-membrane Pressure After CIP - This is the instantaneous pressure across the membrane unit indicated on the membrane unit computer control system just after a CIP of the membrane unit. This will aid the operator in noting how well the membrane unit recovers after a CIP and will help the operator to determine when membranes may need to be replaced.
- Cleaning Solutions Used – List the various cleaning solutions, acids, alkali's, etc. used during the CIP process.
- Cleaning Solution Temperature – List the temperature of the cleaning solution which will verify the water heater is operating properly.
- pH of Rinse Water After CIP – The operator must report the pH and any other water quality test results on the water used to rinse the membrane unit after a CIP has been completed in order to confirm that all of the chemicals used to perform the CIP have been removed from the membrane unit before the membrane unit may go back into service. The specific analyses needed is dependent on the cleaning solutions used and will be specific for each plant.

Summary Report

The operator is to include a summary report of the maintenance performed on the membrane modules or the unit including:

- pinning of broken fibers
- replacement of modules
- repairs to module seals
- DITs which were triggered by indirect monitoring
- Alarm or shutdown conditions and follow up diagnostic testing and repair